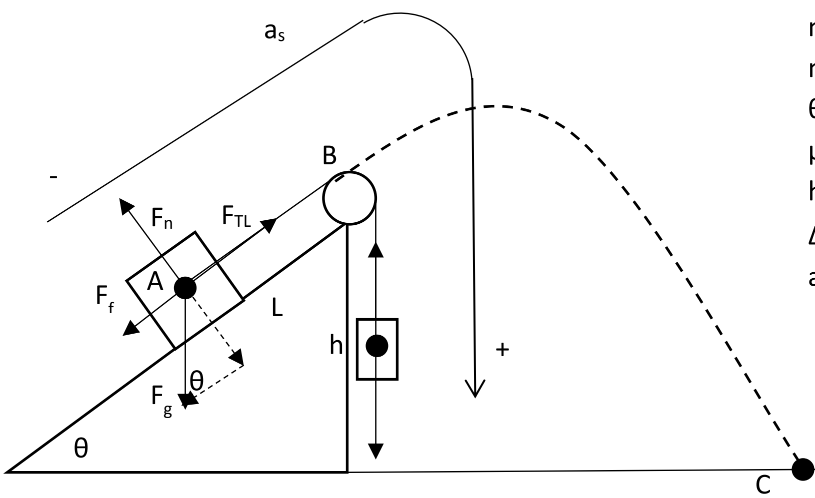
Larry's Long Launch

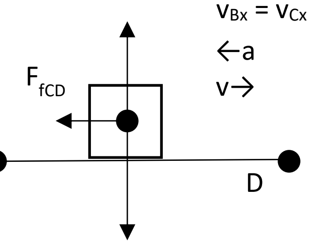
Grant Perkins November 2, 2018 Section H

Description

Leaping Larry decided to make a laborious launcher for his luxury luge using a pulley and ramp system (see diagram). His method was to attach one end of a massless stretchless rope to a barrel of rocks with a mass of 41 kg and to hold the other end of the rope, the mass of Larry and the luge being 30 kg. He placed the rope over a massless frictionless pulley, and then walked down the ramp 7.1 m. When he sat in the luge he accelerated up the ramp to point B and then launched off the top at 31° (all while releasing the rope and avoiding the pulley). He flew through the air as a projectile to point C, transitioning all of his speed into the horizontal direction, and eventually slid to a stop at point D.

Diagram





Givens, Assumptions, and Equations

$m_L = 30$ kg	$v_A = 0$ m/s	$F = ma_{net}$
$m_B = 41$ kg	$t_A = 0$ s	$F_g=mg$
$\theta = 31°$	$v_D = 0$ m	$F_f = \mu F_N$
$\mu_R=.13$	$v_{yC} = 0$ m	$v_f^2 = v_i^2+2a\Delta x$
$h = 7.1$ m	$F_{TL} = F_{TB}$	$x_f = \frac{1}{2}a\Delta t^2 + v_i\Delta t + x_i$
$\Delta x_{BD} = 55$ m	$L = h$	$v_y = \sin(\theta)v$
$a_{BCy} = -9.8$ m/s^2	$y_B = h$	$v_x = \cos(\theta)v$
	$v_{Bx} = v_{Cx}$	$\Delta x_{CD} = \Delta x_{BD} - \Delta x_{BC}$
	←a	$a^2 + b^2 = c^2$
	v→	

Strategy

1. Find the sum of all forces in the ramp system y forces on the luge
2. Find F_{NR} in terms of F_{gLR}, then F_{fR} in terms of F_g
3. Subsitute newly found values into sum of forces
4. Subsitute given values into equation, solve for a_S
5. Subsitute a_S into equation 4, solve for v_B
6. Find v_{BX} and v_{By}
7. Subsitute v_{By} into equation 3, solve for t
8. Subsitute v_{Bx} and t into equation 3, solve for Δx_{BC}
9. Subtract Δx_{BC} from Δx_{BD} to find Δx_{CD}
10. Subsitute v_{By} into equation 4, solve for v_{Cy}
11. Use Pythagorean theorem to find v_c
12. Convert v_C to v_{Cx}, substitute into equation 4, solve a_{CDx}
13. Find sum of forces on luge on ground in x and y
14. Find F_{fG} in terms of F_{gG}
15. Find μ_G in terms of a_{CDx}
16. Solve for μ_G

Find μ$_G$

$$\sum F_s:\ F_{TL} - F_{fL} - \sin\theta F_{gL} - F_{TB} + F_{gB} = m_s a_s$$

$$\sum F_s: F_{NL} - cos\theta F_{gL} = 0$$

$$F_{NL} = \ cos\theta F_{gL}$$

$$F_{fL} = \mu_R cos\theta F_{gL}$$

$$-\mu_R cos\theta F_{gL} - sin\theta \mu_R F_{gL} + F_{gB} = m_s a_s$$

$$a_s = \frac{-\mu_R cos\theta m_L g - sin\theta m_L g + m_B g}{m_L + m_B}$$

$$a_s = \frac{-(1.3)(cos31)(9.8) - (sin31)(30)(9.8) + (41)(9.8)}{30 + 41}$$

$$a_s = \frac{-32.7609 - 151.421 + 401.8}{71}$$

$$a_s = \frac{217.618}{71}$$

$\underline{a_s = 3.06504\ m/s^2}$

$$v_B{}^2 = v_A{}^2 + 2a_s\Delta x$$

$$v_B{}^2 = 0^2 + 2(3.06504)(7.1)$$

$$\sqrt{v_B{}^2} = \sqrt{43.5236}$$

$\underline{v_B = 6.59724\ m/s}$

$$v_{By} = (sin31)(6.59724)$$

$\underline{v_{By} = 3.39784\ m/s}$

$$v_{Bx} = (cos31)(6.59724)$$

$$v_{Bx} = 5.65494\ m/s$$

$$0 = \tfrac{1}{2}at^2 + v_{By}t + y_B$$

$0 = \tfrac{1}{2}(-9.8)t^2 + 3.39784t + 7.1$ **SOLVER**

$\underline{t = \ \cancel{-0.89778}, 1.59122\ s}$

$$\Delta x_{BC} = \tfrac{1}{2}at^2 + v_{Bx}t + x_B$$

$$\Delta x_{BC} = 0 + (5.65494)(1.59122) + 0$$

$\underline{\Delta x_{BC} = 8.99825\ m}$

$$\Delta x_{CD} = 55 - 8.99825$$

$\underline{\Delta x_{CD} = 46.0075}$

$$v_{Cy}{}^2 = v_{By}{}^2 + 2a_y\Delta x$$

$$v_{Cy}{}^2 = 3.39784^2 + 2(-9.8)(-7.1)$$

$$\sqrt{v_{Cy}{}^2} = \sqrt{150.705}$$

$\underline{v_{Cy}{}^2 = 12.2762\ m/s}$

$$v_c{}^2 = v_{cx}{}^2 + v_{cy}{}^2$$

$$v_c = \sqrt{5.65494^{\ 2} + 12.2762^{\ 2}}$$

$\underline{v_c = 13.5137\ m/s}$

$$v_{Dx}{}^2 = v_c{}^2 - 2a_{CD}\Delta x_{CD}$$

$$0 = 13.5137^{\ 2} - 2a_{CD}(46.0075)$$

$$a_{CD} = -\frac{13.5137^{\ 2}}{(2)(46.0075)}$$

$\underline{a_{CD} = -1.98468}$

$$\sum F_x: -F_{fB} = m_L a_{CD}$$

$$\sum F_y: F_{NG} - F_{gG} = 0$$

$$F_{NG} = F_{gG}$$

$$F_{fB} = \mu_G m_L g$$

$$-\mu_G m_L g \ = m_L a_{CD}$$

$$a_{CD} = -\mu_G g$$

$$\mu_G = -\frac{a_{CD}}{g}$$

$$\mu_G = -\frac{-1.98468}{9.8}$$

$$\boxed{\mu_G = -0.20252}$$